(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
6 December 2001 (06.12.2001)

PCT

(10) International Publication Number
WO 01/92200 A1

(51) International Patent Classification[7]: C07C 67/347, 69/003, 69/017, 69/743, 69/753, 61/04, 69/96, 233/58

(21) International Application Number: PCT/SE01/01240

(22) International Filing Date: 31 May 2001 (31.05.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0013487.4 2 June 2000 (02.06.2000) GB
0002101-4 6 June 2000 (06.06.2000) SE

(71) Applicant *(for all designated States except US)*: **ASTRAZENECA AB** [SE/SE]; S-151 85 Södertälje (SE).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **CLARK, Adrian** [AU/SE]; AstraZeneca R & D Södertälje, S-151 85 Södertälje (SE). **JONES, Elfyn** [GB/SE]; AstraZeneca R & D Södertälje, S-151 85 Södertälje (SE). **LARSSON, Ulf** [SE/SE]; AstraZeneca R & D Södertälje, S-151 85 Södertälje (SE). **MINIDIS, Anna** [SE/SE]; AstraZeneca R & D Södertälje, S-151 85 Södertälje (SE).

(74) Agent: **ASTRAZENECA AB**; Global Intellectual Property, S-151 85 Södertälje (SE).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

**Published:**
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

WO 01/92200 A1

(54) Title: PROCESS FOR THE PREPARATION OF CYCLOPROPYL CARBOXYLIC ACID ESTERS AND DERIVATIVES

(57) Abstract: The invention relates to a novel process for the preparation of certain cyclopropyl carboxylic acid esters and other cyclopropyl carboxylic acid derivatives; a novel process for the preparation of dimethylsulfoxonium methylide and dimethylsulfonium methylide; to the use of certain cyclopropyl carboxylic acid esters in a process for the preparation of intermediates that can be used in the synthesis of pharmaceutically active entities; and to certain intermediates provided by these processes.

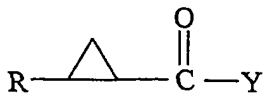
# PROCESS FOR THE PREPARATION OF CYCLOPROPYL CARBOXYLIC ACID ESTERS AND DERIVATIVES

## FIELD OF THE INVENTION

The present invention relates to a novel process for the preparation of certain cyclopropyl carboxylic acid esters and other cyclopropyl carboxylic acid derivatives; a novel process for the preparation of dimethylsulfoxonium methylide and dimethylsulfonium methylide; to the use of certain cyclopropyl carboxylic acid esters in a process for the preparation of intermediates that can be used in the synthesis of pharmaceutically active entities; and to certain intermediates provided by these processes.

## DESCRIPTION OF THE INVENTION

In a first aspect the invention therefore provides a process for the preparation of a compound of formula (I):



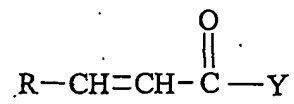
(I)

wherein:

R is phenyl substituted with one or more halogen;

Y is $OR^1$, where $R^1$ is a straight chain alkyl, branched alkyl, cycloalkyl, or a substituted bicycloheptyl group (eg bornyl),

which comprises contacting a compound of formula (II):



(II)

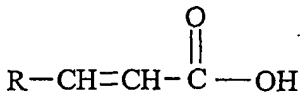
where R and Y are as defined above, with dimethylsulfoxonium methylide in the presence of a solvent.

Suitably the solvent is a polar solvent, preferably dimethyl sulfoxide. Suitably, the reaction is carried out at -10°C - 90°C, preferably 25°C.

The dimethylsulfoxonium methylide can be prepared by reacting a trimethylsulfoxonium salt with a solid strong base, preferably in solid form, in dimethyl sulfoxide at ambient or an elevated temperature. Suitably, the base is a metal hydroxide, eg NaOH, LiOH, or alkali metal hydride, eg NaH. Preferably the base is sodium hydroxide.

Preferably, trimethylsulfoxonium iodide is stirred with sodium hydroxide powder in dimethyl sulfoxide (in the absence of a phase transfer catalyst), optionally under nitrogen, at 20-25°C for 90 minutes. Alternatively, the dimethylsulfoxonium methylide can be prepared from a trimethylsulfoxonium salt (preferably iodide or chloride) using sodium hydroxide in dimethyl sulfoxide with a phase transfer catalyst, for example tetrabutyl-n-ammonium bromide, or with other strong bases, such as alkali metal hydrides, in dimethyl sulfoxide.

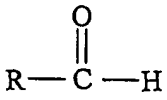
A compound of formula (II) can be prepared by reacting a compound of formula (III):



(III)

where R is as defined above, with a suitable chlorinating agent in the presence of an inert solvent and an optional catalyst at at a temperature of 0-200°C. Preferably Y is $OR^1$, the chlorinating agent is thionyl chloride, the inert solvent is toluene, and the catalyst is pyridine. Suitably the reaction temperature is 70°C. The resulting acid chloride is then reacted with YH or $Y^-$, (where $Y^-$ is an anionic species of Y), Y is as defined above, optionally at an elevated temperature, such as 100°C.

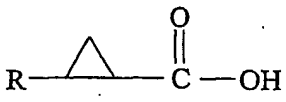
A compound of formula (III) can be prepared using standard chemistry, for example by contacting a compound of formula (IV):



(IV)

where R is as defined above, with malonic acid in the presence of pyridine and piperidine at an elevated temperature, preferably 50-90°C.

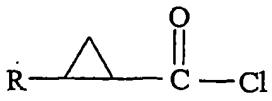
A compound of formula (I) can be hydrolysed using basic hydrolysis to yield a compound of formula (V):



(V)

where R is as defined above. For example, ester groups are preferably removed by basic hydrolysis using an alkali metal hydroxide, such as sodium hydroxide or lithium hydroxide, or quaternary ammonium hydroxide in a solvent, such as water, an aqueous alcohol or aqueous tetrahydrofuran, at a temperature from 10 - 100°C. Most preferably the base is sodium hydroxide, the solvent is ethanol, and the reaction temperature is 50°C.

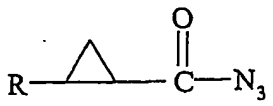
A compound of formula (V) can be used to generate a compound of formula (VI):



(VI)

where R is as defined above, by reaction with thionyl chloride or another suitable chlorinating agent in the presence of toluene, or another suitable solvent, and an optional catalyst, preferably pyridine, at 0-200°C. Preferably the temperature is to 65-70°C.

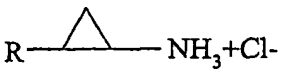
A compound of formula (VI) can be used in the synthesis of a compound of formula (VII):



(VII)

where R is as defined above, by reaction with an alkali metal azide (preferably sodium azide) in the presence of a phase transfer catalyst (preferably tetra-*n*-butylammonium bromide), aqueous potassium carbonate and an inert solvent (preferably toluene). Preferably the reaction temperature is 0 - 10°C.

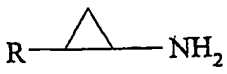
A compound of formula (VII) can be used in the synthesis of a compound of formula (VIII):



(VIII)

where R is as defined above, by rearrangement in toluene at temperatures between 0°C and 200°C, preferably at a reaction temperature of 90-100°C, after which the isocyanate intermediate is reacted with hydrochloric acid at elevated temperatures, preferably 85-90°C.

An unprotonated parent amine (free base) of formula (IX):



(IX)

where R is as defined above, can be liberated by adjusting the pH of an aqueous solution of the salt of a compound of formula (VIII) to 10 or more. This can then be converted to other salts of organic acids or inorganic acids, preferably mandelic acid. The *R*-(-)-mandelic acid

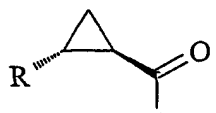
salt of a compound of formula (IX) can be generated by addition of *R*-(-)-mandelic acid at ambient or an elevated temperature to a solution of a compound of formula (IX) in a solvent, preferably ethyl acetate. Preferably the temperature is 20°C.

Suitably R is phenyl optionally substituted by one or more halogen atoms. Preferably, R is phenyl substituted by one or more fluorine atoms. More preferably R is 4-fluorophenyl or 3,4-difluorophenyl.

Preferably Y is D-menthoxy, or more preferably, L-menthoxy.

Compounds of formulae (I) to (IX) can exist in different isomeric forms (such as cis/trans, enantiomers, or diastereoisomers). The process of this invention includes all such isomeric forms and mixtures thereof in all proportions.

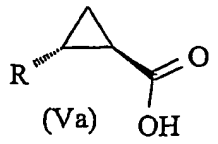
Where Y is chiral, a compound of formula (I) will be a mixture of diastereoisomers and can be resolved to yield a diastereomerically-enriched compound of formula (Ia):




(Ia)

where R and Y are as defined above, by crystallisation or by chromatographic methods. Preferably the crystallisation is carried out *in situ* following the synthesis of a compound of formula (I), as described above, by heating the crude reaction mixture until total or near-total dissolution is achieved, then cooling at an appropriate rate until sufficient crystals of the desired quality are formed. The crystals are then collected by filtration. Alternatively, the resolution can be carried out in any other suitable solvent, such as a hydrocarbon, eg heptane by extracting a compound of formula (I) into a suitable amount of the solvent, heating the extracts until total dissolution is achieved, then cooling at an appropriate rate until sufficient crystals of the desired quality are formed. Optionally the organic extracts can be washed with water, dried over magnesium sulfate and filtered prior to the crystallisation described above.

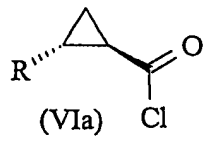
A compound of formula (Ia) can be hydrolysed to yield a compound of formula (Va):




(Va)

where R is as defined above, using the method described above for the hydrolysis of a compound of formula (I) to yield a compound of formula (V).

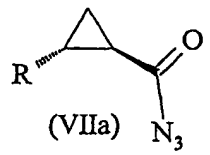
A compound of formula (Va) can be used to generate a compound of formula (VIa):




(VIa)

where R is as defined above, using the method described above for the conversion of a compound of formula (V) to yield a compound of formula (VI).

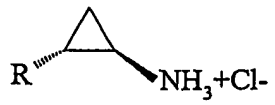
A compound of formula (VIa) can be used in the synthesis of a compound of formula (VIIa):




(VIIa)

where R is as defined above, using the method described above for the conversion of a compound of formula (VI) to yield a compound of formula (VII).

A compound of formula (VIIa) can be used in the synthesis of a compound of formula (VIIIa):



(VIIIa)

where R is as defined above, using the method described above for the conversion of a compound of formula (VII) to yield a compound of formula (VIII).

A compound of formula (VIIIa) can be used in the synthesis of a compound of formula (IXa):

(IXa)

where R is as defined above, using the method described above for the conversion of a compound of formula (VIII) to yield a compound of formula (IX).

The *R*-(-)-mandelic acid salt of a compound of formula (IXa) can be generated using the method described above for the generation of the mandelic acid salt of a compound of formula (IX).

Novel compounds form a further aspect of the invention. In a further aspect the invention therefore provides compounds of formula (I), (Ia), (II), (III), (V), (Va), (VI), (VIa), (VII), (VIIa), (VIII), (VIIIa), (IX) and (IXa) as defined above.

Particularly preferred compounds include:

(1*R*, 2*S*, 5*R*)-2-isopropyl-5-methylcyclohexyl *trans*-2-(3,4-difluorophenyl)cyclopropanecarboxylate;

(1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl *trans*- (1*R*, *2R*)-2-(3,4-difluorophenyl)cyclopropane carboxylate;

(1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl (*E*)-3-(3,4-difluorophenyl)-2-propenoate;

(*E*)-3-(3,4-difluorophenyl)-2-propenoic acid;

(*E*)-3-(3,4-difluorophenyl)-2-propenoyl chloride;
*trans*-(1*R*, 2*R*)-2-(3,4-difluorophenyl)cyclopropanecarboxylic acid;
*trans*-(1*R*, 2*R*)-2-(3,4-difluorophenyl)cyclopropanecarbonyl chloride;
*trans*-(1*R*, 2*R*)-2-(3,4-difluorophenyl)cyclopropanecarbonyl azide;
*trans*-(1*R*,2*S*)-2-(3,4-difluorophenyl) cyclopropyl amine;
and *trans*-(1*R*,2*S*)-2-(3,4-difluorophenyl)cyclopropanaminium (2*R*)-2-hydroxy-2-phenylethanoate

**Examples**

The invention is illustrated by the following non-limiting examples.

**Example 1.**

This example illustrates the preparation of (E)-3-(3,4-difluorophenyl)-2-propenoic acid

A stirred mixture of pyridine (15.5 kg) and piperidine (0.72 kg) were heated to 90°C. Malonic acid (17.6 kg) was added, followed by slow addition, over 50 minutes, of 3,4-difluorobenzaldehyde (12.0 kg). The reaction mixture was stirred at 90°C for a further 4 hours and 36 minutes. Water (58.5 kg) was added and 32 litres of the pyridine/water mixture then was distilled out of the reactor under reduced pressure. The reaction mixture was acidified to pH 1 with 37% hydrochloric acid (6.4 kg) over a 40-minute period, then cooled to 25°C with strong stirring. The solids were collected by filtration, washed twice with 1 % hydrochloric acid (34.8 L per wash), once with water (61 L) and then deliquored thoroughly in the filter. The product was then dried under vacuum at 40°C for 24 hours and 40 minutes, affording 13.7 kg of the crystalline product.

**Example 2.**

This example illustrates the preparation of (*E*)-3-(3,4-difluorophenyl)-2-propenoyl chloride.

A stirred mixture of (*E*)-3-(3,4-difluorophenyl)-2-propenoic acid (8.2 kg), toluene (7.4kg) and pyridine (0.18kg) was heated to 65°C and then thionyl chloride (7.4kg) was added over 30 minutes. The reaction was stirred for a further 2h 15 minutes after the addition was

complete, then diluted with toluene (8.7kg). Excess thionyl chloride, sulfur dioxide and hydrogen chloride were then distilled out, together with toluene (10 L), under reduced pressure, yielding a solution of the (*E*)-3-(3,4-difluorophenyl)-2-propenoyl chloride (approximately 9 kg) in toluene.

**Example 3.**

This example illustrates the preparation of (1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl (*E*)-3-(3,4-difluorophenyl)-2-propenoate.

A solution of *L*-menthol (7.1kg) in toluene (8.5kg) was added over a 20 minute period to the solution of (*E*)-3-(3,4-difluorophenyl)-2-propenoyl chloride (prepared as in Example 2) and pyridine (0.18kg, 2.28 mol) stirring at 65°C. The reaction mixture was stirred at 65°C for a further 4 hours and 40 minutes after the addition was complete, then cooled to 25°C and stirred for a 14 hours. The solution was diluted with toluene (16kg), washed with 5% aqueous sodium chloride (6.4kg), then 6% sodium hydrogen carbonate (6.47kg), then water (6.1kg). The solution was dried azeotropically by distillation of the solvent (20 L) under reduced pressure. Dimethyl sulfoxide (33.9 kg) was added and the remaining toluene was distilled off under reduced pressure, affording 47.3kg of a solution of (1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl (*E*)-3-(3,4-difluorophenyl)-2-propenoate (approx. 13.3 kg) in dimethyl sulfoxide.

**Example 4.**

This example illustrates a method of preparing dimethylsulfoxonium methylide (dimethyl(methylene)oxo-$\lambda^6$-sulfane).

Sodium hydroxide powder (1.2kg), prepared by milling sodium hydroxide pellets in a rotary mill through a 1mm metal sieve, and trimethylsulfoxonium iodide (6.2kg) were stirred in dimethyl sulfoxide (25.2kg) under a nitrogen atmosphere at 25°C for 90 min. The solution was used directly in the preparation of (1*R*, 2*S*, 5*R*)-2-isopropyl-5-methylcyclohexyl *trans*-2-(3,4-difluorophenyl)cyclopropanecarboxylate.

**Example 5.**

This example illustrates a method of preparing dimethylsulfonium methylide (dimethyl(methylene)-$\lambda^4$-sulfane).

Sodium hydroxide powder (970mg), prepared by milling sodium hydroxide pellets in a rotary mill through a 1mm metal sieve, and trimethylsulfonium iodide (4.66 g) were stirred in dimethyl sulfoxide (17 ml) under a nitrogen atmosphere at 20-25°C for 10 min. The solution was used directly in the preparation of (1*R*, 2*S*, 5*R*)-2-isopropyl-5-methylcyclohexyl *trans*-2-(3,4-difluorophenyl)cyclopropanecarboxylate.

**Example 6.**

This example illustrates the preparation of (1*R*, 2*S*, 5*R*)-2-isopropyl-5-methylcyclohexyl *trans*-2-(3,4-difluorophenyl)cyclopropanecarboxylate

A solution of (1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl 3,4-difluorophenyl)-2-propenoate (approximately 8.6 kg) in dimethyl sulfoxide (approximately 27.9 kg) was added with stirring over 20 minutes to a mixture of dimethylsulfoxonium methylide (approximately 2.6kg, prepared as described above), sodium iodide ( (*E*)-3-(approximately 4.2 kg), water (approximately 500 g) and sodium hydroxide (approximately 56 g) in dimethylsulfoxide (27.7 kg) at 25°C. The reaction mixture was stirred for a further 2 hours and 50 minutes at 25°C, then used directly for the preparation of (1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl *trans*-(1*R*,2*R*)-2-(3,4-difluorophenyl)cyclopropanecarboxylate.

**Example 7.**

This example illustrates the preparation of (1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl *trans*-(1*R*,2*R*)-2-(3,4-difluorophenyl)cyclopropanecarboxylate

A crude solution of (1*R*, 2*S*, 5*R*)-2-isopropyl-5-methylcyclohexyl *trans*-2-(3,4-difluorophenyl)cyclopropanecarboxylate produced as described in example 6 was heated with stirring from 25°C to 50°C over a 1 hour period and the temperature was maintained for a further hour. The mixture was then cooled with stirring from 50°C to 35°C over 4 hours, kept at 35°C for 1 hour, then cooled to 26°C over 4 hours, kept at 26°C for 1 hour,

then cooled to 19°C over 3 hours and kept at 19°C for 5 hours and 10 minutes. The product crystallised and was collected by filtration, affording a crystalline solid (2.7 kg) which was shown to contain a mixture of (1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl *trans*-(1*R*,2*R*)-2-(3,4-difluorophenyl)cyclopropanecarboxylate (1.99 kg) and (1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl *trans*-(1*S*,2*S*)-2-(3,4-difluorophenyl)cyclopropanecarboxylate (85 g).

**Example 8.**

This example illustrates an alternative method of preparing (1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl *trans*-(1*R*,2*R*)-2-(3,4-difluorophenyl)cyclopropanecarboxylate

n-Heptane (82.5 L) was distilled under reduced pressure from a solution of (1*R*, 2*S*, 5*R*)-2-isopropyl-5-methylcyclohexyl *trans*-2-(3,4-difluorophenyl)cyclopropanecarboxylate (14.3 kg, 44.4 mol) in heptane (128.6 L). The mixture was then cooled from 34°C to 24°C over a period of 3 hours and 20 minutes. Seed crystals of (1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl *trans*-(1*R*,2*R*)-2-(3,4-difluorophenyl)cyclopropanecarboxylate were then added and the mixture was cooled to 0°C over a period of 5 hours and 50 minutes. Filtration afforded the product as a crystalline solvent wet solid (7.05 kg) which was shown to contain a mixture of (1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl *trans*-(1*R*,2*R*)-2-(3,4-difluorophenyl)cyclopropanecarboxylate (4.7 kg) and (1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl *trans*-(1*S*,2*S*)-2-(3,4-difluorophenyl)cyclopropanecarboxylate (1.1 kg).

**Example 9.**

This example illustrates a method of preparing *trans*-(1*R*, 2*R*)-2-(3,4-difluorophenyl)cyclopropanecarboxylic acid.

(1*R*,2*S*,5*R*)-2-isoPropyl-5-methylcyclohexyl *trans*-(1*R*,2*R*)-2-(3,4-difluorophenyl)cyclopropanecarboxylate (9.6 kg, 91.8% diastereomeric excess) was dissolved in ethanol (13.8 kg) and heated with stirring to 46°C. 45% Aqueous sodium hydroxide (3.1 kg) was added over a 20 minute period and the mixture was stirred for a further 2 hours and 27 minutes. Solvent (28 L) was distilled out of the mixture under reduced pressure, then the mixture was cooled to 24°C and diluted with water (29.3 kg), after which the liberated menthol was extracted into toluene (3 washes of 3.3 kg each).

The remaining aqueous material was acidified to pH 2 with 37% hydrochloric acid (3.3 L) and the product was extracted into toluene (8.6 kg, then 2 more washes of 4.2 kg and 4.3 kg). The combined toluene extracts were washed with 1% hydrochloric acid (4.9 L), then diluted with further toluene (4.2 kg) and azeotropically dried by distillation of the solvent (25 L) under reduced pressure. A final dilution with toluene (24.2kg) was followed by distillation of the solvent under reduced pressure (10 L) affording a solution containing *trans*-(1*R*, 2*R*)-2-(3,4-difluorophenyl)cyclopropanecarboxylic acid (approximately 3.45 kg) suitable for the production of *trans*-(1*R*, 2*R*)-2-(3,4-difluorophenyl)cyclopropanecarbonyl chloride.

**Example 10.**

This example illustrates a method of preparing *trans*-(1*R*, 2*R*)-2-(3,4-difluorophenyl)cyclopropanecarbonyl chloride .

Pyridine (70 ml) was added to a solution of *trans*-(1*R*, 2*R*)-2-(3,4-difluorophenyl)cyclopropanecarboxylic acid (approximately 3.45 kg) in toluene (approximately 12 -15 kg) prepared as described above,and the mixture was then heated to 65°C. Thionyl chloride (2.3kg) was added over a period of 1 hour and the mixture was stirred at 70°C for 3 hours. Thionyl chloride (0.5 kg) was added and the mixture was stirred a further 2 hours at 70°C. A final aliquot of thionyl chloride (0.5 kg) was added and the reaction mixture was stirred for 1 hour at 70°C, then cooled to 40°C. Periodic additions of toluene (45 kg, 3 additions of 15 kg each) were made during distillation of solvent (approximately 60 L) from the mixture under reduced pressure, then the solution of *trans*-(1*R*, 2*R*)-2-(3,4-difluorophenyl)cyclopropanecarbonyl chloride (approximately 3.8 kg) in toluene (approximately 6 - 9 L) was cooled to 20°C.

**Example 11.**

This example illustrates a method of preparing *trans*-(1*R*, 2*R*)-2-(3,4-difluorophenyl)cyclopropanecarbonyl azide.

A solution of *trans*-(1*R*, 2*R*)-2-(3,4-difluorophenyl)cyclopropanecarbonyl chloride (approximately 3.8 kg) in toluene (approximately 6 - 9 L) at 1°C was added over a period

of 74 minutes to a mixture of sodium azide (1.24 kg), tetrabutylammonium bromide (56 g) and sodium carbonate (922 g,) in water (6.2 kg), stirring at 1.5°C. The mixture was stirred at 0°C for 1 hour and 55 minutes, then the aqueous layer was diluted with cold water (3.8 kg), stirred briefly, then separated. The toluene layer was washed once more at 0°C with water (3.8 kg), then with 20% aqueous sodium chloride (3.8 L), then stored at 3°C for further use.

**Example 12.**

This example illustrates a method of preparing *trans*-(1*R*,2*S*)-2-(3,4-difluorophenyl)cyclopropylamine.

A cold solution of *trans*-(1*R*, 2*R*)-2-(3,4-difluorophenyl)cyclopropanecarbonyl azide prepared as described in Example 11 was added over a period of 41 minutes to toluene (6.0 kg) stirring at 100°C. The mixture was stirred for a further 55 minutes at 100°C, then cooled to 20°C and added over a period of 2 hours and 15 minutes to hydrochloric acid (3M, 18.2 kg) stirring at 80°C After 65 minutes the solution was diluted with water (34 kg) and cooled to 25°C. The toluene layer was removed and the aqueous layer was basified to pH 12 with 45% sodium hydroxide (3.8 kg) and the product was then extracted into ethyl acetate (31 kg) and washed twice with water (13.7 kg per wash), affording a solution containing *trans*-(1*R*,2*S*)-2-(3,4-difluorophenyl)cyclopropylamine (2.6 kg, 91.8% enantiomeric excess) in ethyl acetate (29.5 L).

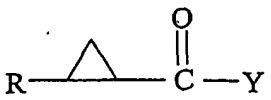
**Example 13.**

This example illustrates a method of preparing *trans*-(1*R*,2*S*)-2-(3,4-difluorophenyl)cyclopropanaminium (2*R*)-2-hydroxy-2-phenylethanoate.

*R*-(-)-Mandelic acid (2.26 kg) was added to a solution containing *trans*-(1*R*,2*S*)-2-(3,4-difluorophenyl)cyclopropylamine (2.6 kg, 91.8% enantiomeric excess), stirring at 17°C in ethyl acetate (45.3 L). The mixture was stirred at 25°C for 3 hours and 8 minutes, then filtered and washed twice with ethyl acetate (13.8 kg total). The crystalline product was dried at 40°C under reduced pressure for 23 hours, affording *trans*-(1*R*,2*S*)-2-(3,4-difluorophenyl)cyclopropanaminium (2*R*)-2-hydroxy-2-phenylethanoate (4.45 kg).

**Claims**

1. A process for the preparation of a compound of formula (I):



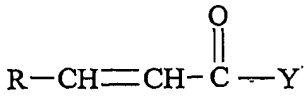
(I)

wherein:

R is phenyl substituted with one or more halogen;

Y is $OR^1$, where $R^1$ is a straight chain alkyl, branched alkyl, cycloalkyl, or a substituted bicycloheptyl group;

which comprises contacting a compound of formula (II):



(II)

where R and Y are as defined above, with dimethylsulfoxonium methylide in the presence of a solvent at a temperature of -10°C - 90°C.

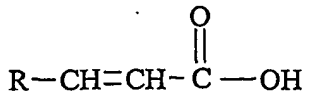
2. A process for the preparation of a compound of formula (I) as claimed in claim 1 comprising the steps of;

i) reacting a trimethylsulfoxonium salt with a solid metal hydroxide in dimethyl sulfoxide at ambient or an elevated temperature to produce dimethylsulfoxonium methylide; and

ii) contacting compound of formula (II) with dimethylsulfoxonium methylide in the presence of a solvent at a temperature of -10°C - 90°C.

3. A process according to claim 2 in which the metal hydroxide is sodium hydroxide.

4. A process according to any one of the preceding claims in which the compound of formula (II) is prepared from a compound of formula (III):



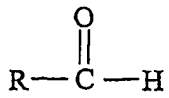
(III)

where R is as defined in claim 1, by reaction with a chlorinating agent in the presence of an inert solvent and a catalyst at at a temperature of 0-200°C, and then reacting the resulting solution with YH or $Y^-$, where Y is as defined in claim 1, at an elevated temperature.

5. A process according to claim 4 in which a compound of formula (III) is reacted with thionyl chloride in the presence of an inert solvent and pyridine at a temperature of 0-200°C, and the resulting solution is then reacted with YH or $Y^-$, where Y is as defined in claim 1, at an elevated temperature.

6. A process according to any one of the preceding claims in which YH represents L-menthol.

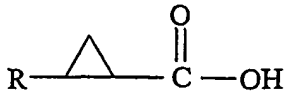
7. A process according to any one of claims 4 to 6 in which a compound of formula (III) is prepared by contacting a compound of formula (IV):



(IV)

where R is as defined in claim 1, with malonic acid in the presence of pyridine and piperidine at elevated temperatures.

8. A process for the preparation of a compound of formula (V):

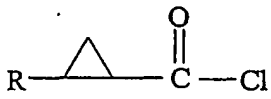


(V)

where R is as defined in claim 1, comprising base hydrolysis of a compound of formula (I).

9. A process according to claim 8 wherein base hydrolysis is achieved using an alkali metal hydroxide and solvent at 10 - 100°C.

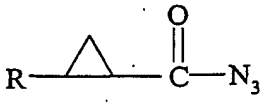
10. A process for the preparation of a compound of formula (VI):



(VI)

where R is as defined in claim 1, from a compound of formula (V) by reaction with thionyl chloride in the presence of solvent and a catalyst at 0-200°C.

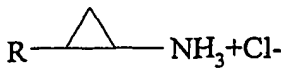
11. A process for the preparation of a compound of formula (VII):



(VII)

where R is as defined in claim 1, from a compound of formula (VI), by reaction with an alkali metal azide in the presence of a phase transfer catalyst, aqueous potassium carbonate and an inert solvent.

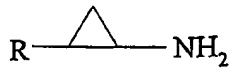
12. A process for the preparation of a compound of formula (VIII):



(VIII)

where R is as defined in claim 1, from a compound of formula (VII), by rearrangement in toluene at elevated temperatures, and subsequent reaction with hydrochloric acid at elevated temperatures.

13. A process for the preparation of a compound of formula (IX):



(IX)

where R is as defined in claim 1, by adjusting to pH 10 or more an aqueous solution of the salt of a compound of formula (VIII).

14. A process for the preparation of a compound the mandelic acid salt of a compound of formula (IX) by addition of *R*-(-)-mandelic acid to the compound of formula (IX) as made in claim 13, at ambient or an elevated temperature.

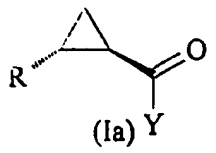
15. A process according to any one of the preceding claims in which R is phenyl substituted by one or more fluorine atoms.

16. A process according to claim 15 in which R is 3,4-difluorophenyl.

17. A process according to any one of the preceding claims in which Y is chiral

18. A process according to claim 17 in which Y is L-menthoxy.

19. A process according to any one of claims 1 to 18 in which a compound of formula (I) is resolved to yield a compound of formula (Ia):




(Ia)

where R and Y are as defined in claim 1, by crystallisation or by chromatrographic methods

20. A process according to claim 19 in which the resolution is carried out by extracting a compound of formula (I) into heptane and then effecting crystallisation from the heptane extracts.

21. The intermediate compounds of formulae (I), (Ia), (II), (III), (V), (Va), (VI), (VIa), (VII), (VIIa), (VIII), (VIIIa), (IX) and (IXa) above.

22. The intermediate compounds;

(1*R*, 2*S*, 5*R*)-2-isopropyl-5-methylcyclohexyl *trans*-2-(3,4-difluorophenyl)cyclopropanecarboxylate;

(1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl *trans*- (1*R*, 2*R*)-2-(3,4-difluorophenyl)cyclopropane carboxylate;

(1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl (*E*)-3-(3,4-difluorophenyl)-2-propenoate;

(*E*)-3-(3,4-difluorophenyl)-2-propenoic acid;

(*E*)-3-(3,4-difluorophenyl)-2-propenoyl chloride;

*trans*-(1*R*, 2*R*)-2-(3,4-difluorophenyl)cyclopropanecarboxylic acid;

*trans*-(1*R*, 2*R*)-2-(3,4-difluorophenyl)cyclopropanecarbonyl chloride;

*trans*-(1*R*, 2*R*)-2-(3,4-difluorophenyl)cyclopropanecarbonyl azide;

*trans*-(1*R*,2*S*)-2-(3,4-difluorophenyl) cyclopropyl amine;

and *trans*-(1*R*,2*S*)-2-(3,4-difluorophenyl)cyclopropanaminium (2*R*)-2-hydroxy-2-phenylethanoate

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 01/01240

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: C07C 67/347, C07C 69/003, C07C 69/017, C07C 69/743, C07C 69/753, C07C 61/04, C07C 69/96, C07C 233/58

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: C07C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | Journal of the American chemicals society, Volume 87, 1965, E. J. Corey et al, "Dimethyloxosulfonium Methylide ((CH3)2SOCH2) and Dimethylsulfonium Methylide ((CH3)2SCH2). Formation and Application to Organic Synthesis" page 1353 - page 1364 | 1-3,15-20 |
| | -- | |
| X | Advanced Organic Chemistry, Fourth Edition, Jerry March, "Reactions, Mechanisms, and structure, John Wiley & Sons, New York, 1992, pages 872, 741 | 1-3,15-20 |
| X | pages 428-429 | 11,15-20 |
| X | pages 1091-1095 | 12,15-20 |
| | -- | |

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 12 October 2001 | 19 -10- 2001 |
| Name and mailing address of the ISA/<br>Swedish Patent Office<br>Box 5055, S-102 42 STOCKHOLM<br>Facsimile No. +46 8 666 02 86 | Authorized officer<br>VIVECA NORÉN/BS<br>Telephone No. +46 8 782 25 00 |

Form PCT/ISA/210 (second sheet) (July 1998)

## INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 01/01240

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 5929291 A (JERZY A. BAJGROWICZ ET AL), 27 July 1999 (27.07.99), scheme 1 and column 4, lines 52-55 | 1-3,15-20 |
| | -- | |
| X | Organic Chemistry, Fifth Edition, T. W. Graham Solomons, John Wiley & Sons, Inc., New York, 1992, pages 781-782 | 8-9,15-20 |
| X | page 775 | 10,15-20 |
| X | pages 846-848; pages 830-832; pages 834-835 | 11-12, 15-20; 13, 15-20;14-20 |
| | -- | |
| X | STN International, File CAPLUS, CAPLUS accession no. 1998:429075, Document no. 129:135904, Diaz-Requejo et al: "BpCu - Catalyzed Cyclopropanation of Olefins: A Simple System That Operates under and Heterogeneous Conditions (Bp = Dihydridobis(pyrazolyl)borate)"; & Organometallics (1998), 17(14), 3051-3057, RN 91393-54-3 | 21-22 |
| | -- | |
| X | STN International, File CAPLUS, CAPLUS accession no. 1998:250346, Document no. 128:321223, Galardon, Erwan et al: "Asymmetric cyclopropanation of alkenes and diazocarbonyl insertion into S-H bonds catalyzed by a chiral porphyrin Ru(II) complex"; & Tetrahedron Lett. (1998), 39(16), 2333-2334, RN 207279-36-5 | 21-22 |
| | -- | |
| X | STN International, File CAPLUS, CAPLUS accession no. 1995:927375, Document no. 124:116326, Demonceau, A. et al: "Cyclopropanation catalyzed by RuCl3 (PPh3)3 and OsCl2(PPh3)3"; Tetrahedron Lett. (1995), 36(46), 8419-22, RN 4103-56-4, 4103-57-5 | 27-22 |
| | -- | |

## INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 01/01240

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | STN International, File CAPLUS, CAPLUS accession no. 1995:597880, Document no. 123:169063, Demonceau, A. et al: "Cyclopropanation of activated olefins catalyzed by Ru-phosphine complexes"; & Tetrahedron Lett. (1995), 36(20), 3519-22, RN 4103-56-4, 4103-57-5 | 21-22 |
| X | STN International, File CAPLUS, CAPLUS accession no. 1998:200362, Document no. 128:270257, Kusuyama, Yoshiaki: "Solvolysis of 1-(trans-2-(m- or p-substituted phenyl) cyclopropyl)-1- methyl--ethyl p- nitrobenzoates"; & Bull. Chem. Soc. Jpn. (1998), 71(3), 685-691, RN 4103-57-5, 205674-79-9 | 21-22 |
| X | Chemical Abstracts, Volume 59 (1962), (Columbus, Ohio, USA), Kaiser, Carl et al, "2-Substituted cyclopropylamines. I. Derivatives and analogs of 2-phenylcyclopropylamine", THE ABSTRACT No 504f, Med. Pharm. Chem. 1962, 5, 1243-1265, RN 91329-59-8, 91393-53-2, 92576-45-9 | 21-22 |
| X | STN International, File CAPLUS, CAPLUS accession no. 2000:6701, Document no. 132:122310, Wu, Xin-Yan et al: "Asymmetric synthesis of 5-hydroxytryptamine receptor agonist (1R,2S)-(-)-2-(2-hydroxyphenyl)-N,N-dipropyl-cyclopropamine"; & Gaodeng Xuexiao Huaxue Xuebao (1999), 20(12), 1892-1896, RN 256431-75-1, 256431-73-9 | 21-22 |
| X | Chemical Abstracts, Volume 57 (1962), (Columbus, Ohio, USA), Richard Fuchs et al, "Transmission of electronic effects by the cyclopropane ring. Ionization constants of m- and p-substituted.beta.-phenylpropionic, cis- and trans-2-phenylcyclopropanecarboxylic acids in 50% ethanol", THE ABSTRACT No 3347i, J. Org. Chem. 1962, 27, 733-736, RN 91329-60-1 | 21-22 |

## INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 01/01240

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | STN International, File CAPLUS, CAPLUS accession no. 1996:148289, Document no. 124:250558, Vallgaarda, Jerk et al: "trans-2-Aryl-N,N-dipropyl--cyclopropylamines: Synthesi and Interactions with 5-HT1A Receptors"; & J. Med. Chem. (1996), 39(7), 1485-93, RN 175168-73-7<br>--- | 21-22 |
| X | WO 9905143 A1 (ASTRA PHARMACEUTICALS LTD.), 4 February 1999 (04.02.99)<br>---<br>-------- | 21-22 |

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/SE 01/01240

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| US 5929291 A | 27/07/99 | EP 0801049 A | 15/10/97 |
| | | EP 1008579 A | 14/06/00 |
| | | JP 10036298 A | 10/02/98 |
| | | US 6162954 A | 19/12/00 |
| | | US 6235943 B | 22/05/01 |
| | | US 6239314 B | 29/05/01 |
| | | US 6284929 B | 04/09/01 |
| WO 9905143 A1 | 04/02/99 | AU 8370698 A | 16/02/99 |
| | | BR 9810802 A | 12/09/00 |
| | | CN 1270590 T | 18/10/00 |
| | | EE 200000044 A | 16/10/00 |
| | | EP 0996621 A | 03/05/00 |
| | | HU 0004333 A | 28/04/01 |
| | | NO 20000312 A | 21/03/00 |
| | | PL 338516 A | 06/11/00 |
| | | SE 9702773 D | 00/00/00 |
| | | SK 188199 A | 09/10/00 |
| | | TR 200000197 T | 00/00/00 |
| | | US 6251910 B | 26/06/01 |
| | | SE 9702775 D | 00/00/00 |
| | | ZA 9806050 A | 06/04/99 |

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE01/01240

**Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

see next sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-3, 8-14, 15-21 (partly)

**Remark on Protest**

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

According to Article 34 (3) (a-c) and Rule 13.2, an international application shall relate to one invention only or to a group of inventions linked by one or more of the same or corresponding "special technical features", i.e. features, that define a contribution which each of the inventions makes over the prior art.

The problem the claimed invention aims to solve is to produce cyclopropyl carboxylic acid esters and other cyclopropyl carboxylic derivatives. This is performed in several steps where the essential step is the formation of a cyclopropyl compound from a α-β-unsaturated carbonyl compound by a reaction with dimethylsulfoxonium metylide (claim 1). Claims 2-3, which are associated with claim 1, describe the process step of claim 1 combined with the preparation of the reagent dimethylsulfoxonium methylide. Claims 4-7 relate to reaction steps leading the reactant of the process in claim 1 and these claims are formally connected to claim 1. Claims 8-14 relate to reactions of cyclopropyl compounds to produce cyclopropyl carboxylic derivatives. Each reaction step is described in independent claims.

The reaction described in claim 1 is however not new (March, J, Advanced organic chemistry: reactions, mechanisms and structure, 4th edition, 1992; Corey, E J, Chaykovsky, M, 1965). As this step is to be considered as the unifying special technical feature, there is no such feature, apart from the prior art, when this reaction is known. Consequently the present application does not fulfil the requirements of unity of invention.

The reactions, claimed in claims 4-14, are completely separated from the reaction described in claim 1. The division into several inventions is based on structural elements of the compounds. The characteristic element of the compound produced according to claim 1 is a substituted cyclopropyl. The reactions according to claims 4-7 do not involve compounds with this element. The reactions following the step in claim 1 do contain this characteristic structural element. However, as these reactions are described in independent claims not formally connected to a unifying step (the step of claim 1) each reaction step is considered to represent an independent invention. These inventions can however be searched for one fee.

.../...

The application also contains claims concerning the intermediate and end products of the process. In order to fulfil the requirements of unity of invention it is necessary that the intermediate compounds are closely interconnected with the end products. Such close connection requires that the essential structural part of the end product is incorporated by the intermediate. In the present invention the essential structural part is, as mentioned, a substituted cyclopropyl. This structural part is however not present in all the compounds claimed.

The application is found to contain the following inventions:

Inventions 1-7: Method for producing compound I and Ia and compounds exhibiting the same essential structural part (a substituted cyclopropyl) namely compounds V, Va, VI, VIa, VII, VIIa, VIII, VIIIa, IX and IXa. The compounds I, Ia, V, Va, VI, VIa, VII, VIIa, VIII, VIIIa, IX, IXa. This is described in claims 1-3, 8-14 and parts of claims 15-21.

Invention 8: Method for producing compound II and compound II. Claims 4-6 and part of claims 15-21.

Invention 9: Method for producing compound III and compound III and IV. Claim 7 and 15-16 partly.

As a consequence of the lack of unity of the application a complete search has not been performed. The search comprises only what is referred to as inventions 1-7 above.